Inventors: Jyh-Chain Lin
Ching Yen Lee

SPECIFICATION

DRIVING CIRCUIT FOR LIGHT EMITTING DIODES

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to an electronic driving apparatus, and particularly to a driving circuit for light emitting diodes (LEDs).

2. Description of Prior Art

[0002] Referring to FIG. 2, in a conventional LED driving circuit, a current limiting resistor 11 is provided between a power supply 10 and an LED array 12 formed by an m×n matrix of light emitting diodes (LEDs) 121. A voltage provided by the power supply 10 is U, a resistance of the current limiting resistor 11 is R, a resistance of each LED 121 is R_S, and a current of a main path is I. The voltage-current (V_F-I_F) characteristic of each LED 121 is shown in FIG. 3, and can be expressed by the following equation:

$$V_F = V_{on} + R_S I_F + (\Delta V_F/\Delta T)(T - 25°C)$$

where V_{on} is a threshold voltage of the LED 121

When a temperature of the environment is constant, the above equation can be simplified as follows:

$$V_F = V_{on} + R_S I_F$$

[0003] Thus the electrical characteristic of the LED driving circuit can be expressed as:

$$U - mV_{on} = I(R + R_S(m/n))$$

Simplifying the above equation yields:

$$U - V_X = I(R + R_X)$$

where $$V_X = m^*V_{on}\ ,\ R_X = R_S(m/n)$$

[0004] Because of the existence of V_{on}, the current I does not change proportionally with the voltage U. For example, when the voltage U changes to 2U, the current I does not double but instead changes to less than 2I. The LED driving circuit cannot regulate the current I proportionally by linearly changing the voltage U provided to the LED array 12. Therefore it is difficult to precisely control the current I.

[0005] Similarly, when a quantity of the LEDs 121 or when a form of the LED array 12 is changed (i.e., V_X and/or R_X is varied), alterations of the voltage U and the resistor R are required in order to control the current I. However, for the reasons described above, such alterations to precisely control the current I are difficult.

[0006] Therefore, it is desirable to provide an improved driving circuit which overcomes the above-described disadvantages of the conventional driving circuit.

SUMMARY OF THE INVENTION

[0007] An object of the present invention is to provide a driving circuit that allows precise control of current.

[0008] In order to achieve the above-described object, a light emitting diode driving circuit in accordance with the present invention includes a current limiting resistor, an FET (Field Effect Transistor), and a feedback circuit. The FET has a drain electrode connected to the current limiting resistor to provide current to a load such as an LED, and the feedback circuit has a variable reference voltage

source for controlling a current of the drain electrode of the FET.

[0009] Other objects, advantages, and novel features of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic view of a driving circuit in accordance with the present invention.

[0011] FIG. 2 is a schematic view of a conventional LED driving circuit.

[0012] FIG. 3 is a graph showing the voltage-current characteristic of each of LEDs in the LED driving circuit of FIG. 2.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0014] Reference now will be made to the drawings to describe the present invention in detail.

[0015] Referring to FIG. 1, a driving circuit 2 for an LED according to the present invention includes a power supply 21, an FET 22, a feedback circuit 23, a current limiting resistor 24, and an LED 25. The FET 22 has a source electrode S, a gate electrode G, and a drain electrode D. The source electrode S is connected to the power supply 21. The current limiting resistor 24 is provided between the drain electrode D of the FET 22 and the LED 25.

[0016] The feedback circuit 23 includes a first differential amplifier 231, a second differential amplifier 232, an integrating circuit 233, and a variable reference voltage source 234. The first differential amplifier 231 has two input terminals, which are connected to two terminals of the current limiting resistor 24, respectively. An output terminal of the amplifier 231 and the variable reference

voltage source 234 are connected to two input terminals of the second differential amplifier 232. An output terminal of the second differential amplifier 232 is connected to the integrating circuit 233, and an output terminal of the integrating circuit 233 is connected to the gate electrode G of the FET 22.

[0017] A voltage provided by the power supply 21 is V_{DD}, a voltage drop of the current limiting resistor 24 is V_{R1}, an output voltage of the first differential amplifier 231 is V_0, an output voltage of the second differential amplifier 232 is V_1, a voltage provided by the variable reference voltage source 234 is V_{REF}, and an output voltage of the integrating circuit 233 is V_G. Thus V_G is a voltage of the gate electrode G of the FET 22. An operating current of the drain electrode D of the FET 22 is i_D. That is, a current in the current limiting resistor 24 and the LED 25. A resistance of the current limiting resistor 24 is R_1, a resistance of a resistor (not labeled) between the power supply 21 and the source electrode S is R_4, and resistances of resistors (not labeled) of the feedback circuit 23 are R_2, R_3 and $R_5 \sim R_{12}$ respectively. A capacitance of a capacitor (not labeled) of the integrating circuit 233 is C_1.

[0018] It would be desirable to use the feedback circuit 23 for stabilizing the operating current i_D in the LED 25. In order to achieve this object, keeping V_{R1} constant is all that is required.

[0019] The two input terminals of the first differential amplifier 231 are connected to the two terminals of the current limiting resistor 24 respectively; therefore V_{R1} is an input signal of the first differential amplifier 231. When $R_{12}/R_3 = R_5/R_2$, V_0 is expressed as:

$$V_0 = -R_5 V_{R1} / R_2 \qquad (1)$$

[0020] The output terminal of the amplifier 231 and the variable reference voltage source 234 are connected to the two input terminals of the second

differential amplifier 232. When $R_{11}/R_{10}=R_8/R_9$, V_1 can be expressed by the following equation:

$$\begin{aligned} V_1 &= -(R_8/R_9)(-R_5V_{R1}/R_2-V_{REF}) \\ &=(R_8/R_9)(R_5V_{R1}/R_2+V_{REF}) \end{aligned} \quad (2)$$

[0021] The output voltage V_1 is input to the integrating circuit 233, and the output voltage of the integrating circuit 233 is V_G. That is, the voltage of the gate electrode G of the FET 22 becomes:

$$\begin{aligned} V_G &= -(1/RC_1) \int V_1 d\,t \\ &= -(1/RC_1) \int (R_8/R_9)(R_5V_{R1}/R_2+V_{REF})\, d\,t \end{aligned} \quad (3)$$

[0022] When the resistances of the resistors R_2, R_3 and $R_5 \sim R_{12}$ are equal, Eq. (3) can be simplified as follows:

$$V_G= -(1/RC_1) \int (V_{R1}+V_{REF})\, d\,t \quad (4)$$

[0023] Because V_G and i_D have a linear relationship, this can be expressed as: $V_G=Ki_D$, where K is a constant. Also, $V_{R1}=i_DR_1$. Substituting these two equations into Eq. (4) yields:

$$Ki_D= -(1/RC_1) \int (i_DR_1+V_{REF})\, d\,t \quad (5)$$

[0024] Differentiating Eq. (5) gives:

$$Ki'_D= -(1/RC_1)(i_DR_1+V_{REF}) \quad (6)$$

Solving for i'_D yields:

$$i'_D= -A\, i_D+B\, V_{REF} \quad (7)$$

where $A=(1/RC_1)R_1/K$

and $$B=(1/RC_1)/K$$

Then the solution of the Eq. (7) is expressed as:

$$i_D=(B\,V_{REF}/A)(1-Exp(-At)) \quad (8)$$

When time t increases, Exp(-At) approaches zero, and finally the following equation is obtained:

$$i_D=B\,V_{REF}/A=V_{REF}/R_1 \quad \text{or}$$

$$i_DR_1=V_{REF} \quad (9)$$

[0025] Equation (9) expresses the linear relationship between the operation current in the LED 25 and the variable reference voltage source 234. Thus the operation current in the LED 25 can be precisely regulated by adjusting the variable reference voltage source 234.

[0026] In this embodiment, the resistances of the resistors R_2, R_3 and $R_5 \sim R_{12}$ in the feedback circuit are equal. If the resistances of said resistors are not equal, then equation (9) is modified to:

$$i_DR_1K_R=V_{REF}$$

Where K_R is a constant, which is determined by the resistances of said resistors. That is, K_R does not affect the linear relationship between the variable reference voltage source 234 and the operation current of the LED 25.

[0027] An LED or an LED array driven by the driving circuit 2 of the present invention can be used as a light source in a field of display or a like apparatus.

[0028] The main advantage of the described embodiment over the prior art is that the driving circuit 2 includes a feedback circuit which stabilizes the operating

current under different loads, and which provides precise current control.

[0029] It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.